

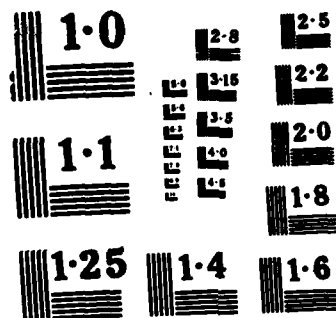
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IDA MEMORANDUM REPORT M-106

COMMERCIAL MARKET POTENTIALS FOR THE  
USE OF THE Ada\* PROGRAMMING LANGUAGE

David Dikel  
Audrey A. Hook  
Patricia L. Greene

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JAN 22 1986  
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August 1985

*Prepared for*  
Office of the Under Secretary of Defense for Research and Engineering

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INSTITUTE FOR DEFENSE ANALYSES  
1801 N. Beauregard Street, Alexandria, Virginia 22311

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INSTITUTE FOR DEFENSE ANALYSES

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# COMMERCIAL MARKET POTENTIALS FOR THE USE OF THE Ada\* PROGRAMMING LANGUAGE

## PREFACE

This report is based upon the results of a survey conducted by David Dikel, Director of Materiel Logistics, of Intellimac, Inc. for The Institute for Defense Analyses. It contains findings of the survey, both general and specific.

## 1.0 INTRODUCTION

This report is based upon research on the use of the Ada language in the commercial community. The formal interview process took place during a seven month period from October 1984 to April 1985. The objective of the study was to investigate and describe areas of commercial Ada use in an effort to encourage better informed investments in the development and implementation of Ada products by the commercial community.



This report is organized into three major sections: Section 1.0--INTRODUCTION, Section 2.0--SPECIFIC FINDINGS and Section 3.0--CONCLUSIONS. INTRODUCTION (Section 1.0), contains METHODOLOGY and GENERAL FINDINGS. SPECIFIC FINDINGS (Section 2.0), includes summaries of projects from the commercial areas of: Avionics; Communications; Process Control; Computer Based Training; Artificial Intelligence; and Geophysical Analysis. CONCLUSIONS (Section 3.0), summarizes the researchers' conclusions based upon their findings. The major sections are followed by four appendices containing additional research data.

## 1.1 RESEARCH METHODOLOGY

Research activity for this project began by recording those Ada applications in the military and commercial sectors for which there were references in the technical literature. Individuals who have used the Ada language in their operations were asked to contribute to lists of new contacts and Ada applications.

Ada users in the military were surveyed to discover what, if any, commercial products had developed as result of their Ada involvement as well as what their own experiences with Ada had been.

An interview questionnaire was designed (See Appendix A) to standardize questions and focus responses. The same questionnaire was used for all those interviewed, whether commercial developers, military developers or vendors. The last item on the interview form was a request for referrals to other Ada users. This was done in an effort to broaden the poll base and to maintain the most up-to-date possible compilation of commercial Ada users.

Researchers attended Ada conferences and reviewed trade and technical literature on the subject. NOSC tools (Ada tools developed for the Naval Ocean System Center under contracts from the World Wide Military Command and Control Information System Joint Program Management Office), along with any other Ada products currently being introduced into the commercial marketplace were investigated.

Intellimac, a Maryland firm specializing in Ada products since 1981, has gained extensive experience with the Ada language, including applications in Artificial Intelligence. Their "Ada experts" were consulted when evaluating the survey questionnaires and some of Intellimac's work with the language is recounted in this document.

## 1.2 GENERAL SURVEY FINDINGS

There were some frequently occurring generic kinds of replies from respondents to the survey. These fall into the following categories:

### 1.2.1 CHARACTERISTICS OF MANY COMMERCIAL Ada PROJECTS

- a. Commercial projects involve a large number of interrelated applications. Some projects exist where design and specification must interface with hardware and software from "outside" and yet, changes in specification must still be carefully managed and controlled.
- b. There are identical software functions that must be capable of execution on multiple processors, architectures or operating systems. The designs call for a layered approach that may run across architectures and/or require an interface to other manufacturers' software.
- c. The code will be maintained over long periods of time.

- d. Market forces demand improved capabilities for less money. Old software must at times be run on hardware other than that for which it was developed, thus creating rewriting, testing and field reliability problems.
- e. Software is a group effort (often formed by pooling software resources within a company). Life cycle cost, maintenance, and training are key concerns for this group.

#### 1.2.2 WHY DEVELOPERS ARE USING Ada

- a. Increasing confidence in Ada technology
- b. Better understanding of Ada: what it is, what it can and cannot do, how well the current products work
- c. Rapidly increasing number of "Ada literate" people (Those who can successfully use Ada to solve a complex software problem)
- d. Better Ada products are becoming available, exhibiting better performance and an improved ability to interface with other languages

e. Department of Defense support for Ada

## 2.0 SPECIFIC FINDINGS BY COMMERCIAL AREA

### 2.1 AVIONICS

Several projects in the field of commercial Avionics were reported by vendors of Ada products. The profile of one such corporate endeavor follows:

#### A. Project Description

Code was being developed for a Flight Control System, Flight Display System, and for a Navigation System. The three projects involved development of over 50K lines of source code. Automated test software was also developed in Ada for these systems. Over 25 programmers are working full time and the company supports a staff to maintain the compiler and code generators. The work is about half complete, and the product will be used for commercial aircraft.

#### B. Reasons for Choosing Ada

1. There is a corporate commitment to work in a high level language whenever possible.
2. They have several target processors with similar functions.

3. Ada allowed them the ability to share code and computer resources with the military side of the corporation.
4. Using one language on the multiple processors reduced the engineering support, training, and maintenance burden.
5. The requirements of complex software and interface functions made it necessary for programmers to work in groups.

C. Project Status

1. They are pleased with the compiler performance to date.
2. The programs were more likely to work the first time than with Assembly or other high level languages.
3. The functions that resulted were more reusable and yet took approximately the same amount of time to develop as with other languages.
4. "Bugs" in the code were easier to identify and repair.



5. Maintaining version control over the many compiler updates across engineering groups presented a problem.
6. The developer provided an engineering support group to write or maintain the various target code generators. This effort resulted in eliminating the need for any Assembly language for several of the target processors.

#### D. Military Influences

One of the first projects to use Ada for an embedded application involved the development of a redundant actuator control system by MOOG, Incorporated for Boeing Military Aircraft Company (BMAC). This application produced a modular and reconfigurable system with many built-in parameters.

This system helped demonstrate the feasibility of Fly-by-Wire (FBW) Systems. Ada code, tools and technology developed for this application have been reused by MOOG for other projects.

This effort produced:

1. The resultant software
2. A decision by MOOG to use Ada in a commercial project

Comments by MOOG developers concerning the project included:

"There were, as there are in all new software, many bugs in the compiler and support package that the software group had to work around. Even with these problems, it is estimated that the development of fully documented code was accomplished in 30% of the time of a similar development done in Assembly language"(1).

"The system ... ran quite reliably"(2).

This experience also resulted in the training of a group skilled in the use of Ada and the availability of new Ada products.

Later uses of Ada, namely Northrup's use of Ada in the F-20 (3), and McDonnell Aircraft's use of the F-15 (4), indicate that real flight performance requirements can be met within the processing time and memory space available with Ada.

The F-20 and F-15 efforts with Ada revealed an increase in programmer productivity and more compact, readable source code.

## 2.2 COMMUNICATIONS

Three compiler vendors surveyed indicated that major commercial communications software efforts were underway in their user communities. One example of the work being undertaken in the communications field is cited below.

### A. Project Description

This project involves the creation of an estimated 2-3 million bytes of object code. The resulting product will be a sophisticated data communications system. The project is now in the design phase; Ada training is well established and several large procurements of Ada tools and development systems have been made.

### B. Reasons for Choosing Ada

1. The customer chose to use a high level language with strong typing and interface checking in the early stages of design.

2. Ada was chosen over two competitors (CHILL and MODULA II) for its strong support from the Department of Defense and the enthusiasm of the Ada user community.

3. The customer perceived Ada to be progressing well in both available tools and technology.

4. There were a number of entry level programmers available from the local university and continued training for Ada programmers at the school was anticipated.

Since the project will span many calendar years in development and presumably many more in the product life, this corporation has put great faith in long-term support for Ada by the DoD and others in the computer field. When contemplating the use of Ada, concern was not only for tools, but for a continuing source of trained people.

This company has several other Ada projects in the works. The investment in a core group of Ada-trained personnel, and in the refinement of Ada tools and utilities allows for a cross-pollination of resources as well as providing a pool of in-house talent. This has led to a significant reduction in their training costs.

#### C. Project Status

1. Cost savings have been experienced by using Ada education programs that had already been developed by the military division of this corporation.

2. So far, they are pleased with their choice of Ada based on new products available and new developments in Ada technology.

#### D. Military Influences

Singer Librascope, working under the direction of the U.S. Army, Ft. Monmouth, New Jersey did some of the earliest work with Ada for embedded communications. Their developments include a multi-layered interface with the Army's own communications network, as well as with the NATO HEROS interface. They have addressed issues such as the use of multiple processors, implementation of X-25, and the pioneering work in using embedded Ada code (5).

Syscon, under contract to Defense Communications Agency, has created a design methodology for implementing communications protocols in Ada. This has resulted in a graphically oriented editor that automatically generates Ada PDL from its graphic symbols as well as a methodology for complex software development (6).

complex software development (6).

As part of the WWMCCS upgrade effort, the WIS program has funded several pilot implementations of the TCP/IP protocol in Ada, along with other important tools that will be distributed to the defense community at no charge. The size and scope of the WIS program will, by its nature, produce a tremendous amount of new communications software. Both the Army and the Air Force have expressed a commitment to the use of Ada in their portions of the WIS program.

### 2.3 PROCESS CONTROL

There have been a few applications of Ada in process control made public. The available feedback indicates that more extensive use of Ada awaits compilers offering both a better, faster tasking mechanism and more compact object code. MOOG, Incorporated, of Buffalo, New York has built a front end to an industrial control system. Their work involved the development of a "Smart CRT" using Ada.

#### A. Project Description

Thirty-four Ada packages were developed, totalling 16,656 lines of source code. In addition, 2400 lines of Assembler source code were developed. The project goals are as follow:

- o "Screen formats fully programmable within the unit
- o Communications data formats programmable within the unit
- o Digital electronics capable of supporting either color or monochrome CRT's.
- o Interface to portable tape cartridge unit to enable:
  - Storage of original configuration data
  - Restoration of configuration data after power failure
  - Transfer of configuration data to multiple units
- o Generic design to allow for application to various industrial controls
- o Evaluation of the use of Ada in an embedded commercial application" (2)

#### B. Reasons for Choosing Ada

1. Good results with a recent military project.

2. Desire to standardize on a single language for control applications
3. Desire to develop a standard library of functions across processors

#### C. Project Status

Their conclusions follow:

Positive aspects of Ada were: readability; reliability; and reduced test time. In addition, they found the following language features useful: package features; exception handling; generics; flexibility of looping structure; strong typing; enumeration data types; and record data types.

Negative aspects were: changing a specification part of a low-level package required time-consuming recompilation of large numbers of packages. Also, task switch time was too long (1.7 msec), preventing the use of tasking in time-critical applications. The expansion ratio of Ada source code into memory was too large. In the case of the Smart CRT, over 400K of PROM was required, with an additional 200K of RAM. Additionally, there was a lack of bit manipulation instructions, non-standard implementation of interrupts and non-standard implementation of embedding Assembler language within an Ada system (2).



As a result of difficulties with the existing implementation, the decision was made not to use Ada in several of the other projects which were being considered for Ada. According to Ada software developer Thomas M. Pepper, the existence of a production quality compiler with acceptable task switch times, and compact code will prompt Ada use in a number of additional projects.

#### D. Military Influences

As reported earlier, MOOG became involved with Ada through the development of a Fly-by-Wire system for BMAC. They later decided to use Ada for a smart terminal and are considering it for a Blow Moulding Machine and other process control applications. As a result of their military work, they developed a "Software Logic Analyzer" written entirely in Ada. In addition to pioneering the use of Ada in several control applications, their development team was instrumental in providing information and support to the fledgling Ada community.

## 2.4 COMPUTER BASED TRAINING

AIS II is a computer based training tool based on an older MacDonnell Douglas product called AIS written in Camel, a language developed some years ago by SofTech.

When contracted by the Air Force to create a training system called Instruction Support Software (ISS), the original AIS (Automated Instruction System) system was redesigned and the Camel code translated into Ada. Because of the success of ISS, it was decided to reuse much of the the Ada code written for this military work and upgrade the old AIS system into AIS II. The result is reported to be a highly modular, easily customizable, and portable computer based training system.

### A. Project Description

The AIS II product features:

CMI (Computer Managed Instruction) including: scheduling of students and instructors; predicting/tracking/recording of student progress, performance and training milestones; revising/updating of schedules, courses, lessons, tests, student and instructor records and progress predictions.

AIS II also contains CAI (Computer Aided Instruction)

with: CAI authoring; CAI presentation; graphics editing; simulation authoring; and simulation presentation. In addition, the product also features natural language design of courseware, course authoring and curriculum design (7).

#### B. Reasons for Choosing Ada

1. The product required modularity.
2. Ada can produce a tool that can be tailored to customer requirements.
3. Parts can be emphasized or a subset of the whole may be selected. For example, CAI can be developed by the vendor for the application and licensed only on a PC or, a full system can be sold for a specific mainframe computer.
4. Portability is required for this kind of application. The same source code has been moved from VAX to Gould to 6800/UNIX, recompiled and run with no changes. CAI portions are developed on minis, then the code is compiled on a PC using an Ada subset and run.
5. The hardware can be changed. The customer may buy only software and the vendor can upgrade hardware without forcing the customer to pay prohibitive software moving costs.

### C. Project Status

Dave Phlaster, Technical Manager for the ISS Project, made the following comments:

"It was a pleasure from a program management standpoint, we met all of our major milestones."

"The project was developed to specification with comparatively little effort."

"Porting to a new architecture is easy."

## 2.5 ARTIFICIAL INTELLIGENCE

There has been some discussion with regard to using Ada for Artificial Intelligence projects. Many of these discussions concern combining Ada with the LISP language or with derivatives of LISP.

### A. Project Description

Intellimac, Inc. was contracted in late 1983 to create a bilingual English-French technical manual production system, completely in Ada. The system has these primary functions: assisting in the rewriting of existing technical manuals

(typically military operations and maintenance) to conform to principles of clear, legible writing; translating the rewritten manuals from English to French (with at least 70% accuracy, no human intervention); and automatically phototypesetting the text into camera-ready format. There are about 25K lines of source code written to date for this effort. The project is approximately 2/3 complete.

#### B. Reasons for Choosing Ada

Dick Naedel, President and founder of Intellimac, recently gave his reasons for his company's use of Ada in an internal publication:

"Ada, unlike other languages which are not inherently structured by design, lends itself very well to the implementation of sound software engineering principles and techniques. Whereas it is very difficult to maintain LISP programs of 10,000 lines or more, Ada remains highly maintainable in systems exceeding hundreds of thousands of lines.

Ada's modular package structure enhances configuration management as the system evolves in size and complexity. Since any two Ada packages need only be concerned with each other's interface specifications, the amount of information stored in a configuration management system

grows arithmetically with the total number of packages.

Because of the typically small size of each package, piecewise unit testing and debugging becomes a straightforward finite process.

It is interesting to note that at the 25,000 line point (2/3 complete), only about 30% of the code could be classed as AI algorithms (parsers, pattern matchers, rules base organizers, etc.) The remaining 70% of the code was comprised of "traditional" procedural functions such as utilities, reports, arithmetic, and database (dictionary) manipulation. As the size of the code increases towards completion, the ratio of procedural to non-procedural code increases. The AI algorithmic content is expected to represent only about 20-25% of the system at the time of completion. Had LISP been employed as the overall system language, it would have been poorly suited for almost 80% of the actual functional requirements.

...it is the experience of this company, however, that the most efficient way to code a large AI applications system for field deployment is to use Ada for the entire system. Only with Ada come the benefits of speed, portability, team programming, maintainability, and lowered life cycle costs" (8).

### C. Project Status

Intellimac representatives report that they are pleased with their choice of Ada for this application. Hobart Mendenhall, Vice President of Software Engineering for Intellimac, performed a COCOMO (Constructive Cost Model) benchmark on this application, as well as several accounting applications. The results were: fewer overall manhours of effort using Ada; development time remains approximately the same; distribution of effort shifts more to the front end of the project (9).

### D. Military Influences

In late 1980, Dick Naedel delivered a study to Naval Surface Weapons Center on the future of Intelligent Associative Memory. In this study he predicted that Ada would be a preferred language for the implementation of the next generation of AI based systems. (10)

## 2.6 GEOPHYSICAL ANALYSIS

A major U.S. oil corporation is in the process of developing a system of Ada software for the support of their exploration effort.

## A. Project Description

This project involves the redesign and implementation of the exploration support software system. Currently, there are over 200 stand alone programs, written in Fortran and Assembler. These functions need to be categorized and put into a library. This library will ensure that they do not have to rewrite code, and that functions are interfaced properly.

These programs are used to process the large amounts of exploration data. They run on several different processors, and need to be modified or even rewritten by the Geophysicist to perform the appropriate analysis.

The goal of this project is the creation of an expert system to support the analysis of exploration data. The objective is to develop an expert system allowing the scientist the ability to generate a program by specifying which functions he wants performed, and their interrelationships. Presently, five people are involved full-time in system design and in requirements and feasibility analyses.

## B. Reasons for Choosing Ada

According to the project manager, maintenance costs for the stand alone programs are "eating us alive". The present code is based on 1960's technology and is poorly documented.



The individual functions are not designed to facilitate a clean interface to other programs.

The reasons given for using Ada were to aid in the design, implementation and maintenance of a programming environment that lowers maintenance costs, enhances the scientists' productivity, and produces more reliable results.

#### C. Project Status

A study of the kind of language and technology needed for the implementation of this project was performed. When the group looked at Ada, they found that it possessed the capabilities required for their application.

#### D. Military Influences

Ada was designed to solve the this type of software problem for the military.

### 3.0 REPORT CONCLUSIONS

#### 3.1 DOD SUPPORT TO Ada

This study revealed the importance of continuing DoD support to the Ada language. Corporations that chose Ada often cited the military support of Ada as an important factor in their decision. There are several specific elements that they reference in this regard.

1. Longevity of Ada Language and Technology
2. Solutions provided for software problems by off-the-shelf technology
3. Software portability assurance due to intelligent language control and maintenance of practical validation standards
4. Development of a marketable capability for the government branch of the corporation.

#### Longevity of Ada Language and Technology:

A manager of a large scale project needs to be assured that the language he chosen for development will still be in

existence ten or twenty years in the future. This will prove more cost-effective in several ways: programmers will not have to be trained in the use and application of a new language for many years; managers will not be burdened with continual refinement of tools and environments for this language; nor will they have to be concerned with moving the language to improved architectures as they evolve. Maintenance costs will be lower because the language that was chosen at the onset was not readily obsolescent.

#### Off-the-Shelf Technology:

DoD support and the increased use of Ada should fuel the creation of products that are beneficial to the developer of Ada software. Such products will soon be available "off-the-shelf" as opposed to being developed for each new application. In addition to these products, some software will be available free of charge to many or all Ada users. Already, several of the NOSC tools are available to many defense contractors at no charge. These include an ongoing implementation of the GKS binding (Graphics Kernel System--part of a graphical editor written in Ada), metrics tools, portable user interfaces, and communication software.

The military's commitment to "Software first" will ensure that target code generators will be developed for new microprocessors. Therefore, the customer will not need to

create his own technology to transfer his application to an improved architecture.

DoD commitment will help to ensure that the Ada software environment will be upgraded continually and these upgrades should some day be purchasable on the open market.

#### Software Portability Assurance:

The DoD's intelligent control of validation will provide the foundation for maximum portability of source code. Lately there has been a trend toward improved capabilities in workstations and multiple processor configurations made from "super-microcomputer" technology. It is likely that a growing company would want to continue to enhance its development environment with lower cost, more highly efficient components as the technology becomes available.

#### Development of a Marketable Ada Capability to Government Customers:

Several of the respondents were from companies with a substantial government business in addition to their commercial market. The training of employees for Ada use on commercial applications was accomplished more easily because training programs acquired for the government operations were reusable on the commercial side. The use of Ada also allowed the

sharing of both code and technology between the two sections of the corporation.

Complimenting the number people proficient in Ada language should be a growing number of standard solutions to common software problems. This will help the manager who discovers he needs a capability that was not included in the original planning.

### 3.2 FACTORS THAT IMPACT CONTINUED Ada USE

1. Ada needs better embedded system support for the generation of more compact, memory efficient code. New compilers are beginning to appear on the market (e.g., the ICSC compiler) that can solve this problem; however, companies using this compiler still require a large in-house support staff.

2. Better run time support systems that meet the requirements of real time use and allow more effective use of tasking for these applications are needed.

3. Better embedded support tools and development environments are required.

4. Continued government insistence on a long term solution to software problems is necessary.

5. Use by DoD of Ada in non mission-critical areas is desired.

6. Continuing DoD support and commitment to the development of the Ada language is crucial to Ada's success.

### 3.3 SUMMARY OF PROJECT EXPERIENCE WITH Ada

- a. The resultant software tends to be more reliable.
- b. The test phase is generally shortened with Ada.
- c. Projects are more likely to stay on schedule.
- d. There is an increase in overall development productivity.
- e. There is an increase in reusable code.
- f. The products are more portable.
- g. Current Ada users are often dissatisfied with available tools and/or compactness/performance of generated code.
- h. Some Ada users plan to increase scope of Ada activity as tools improve.
- i. Current Ada users are often displeased with present task switch times.
- j. Users of several Ada compilers were unhappy with

object code size.

- k. There are a number of "pilot projects" using Ada in major commercial concerns.
- l. There are a major Ada applications in development.
- m. There is increasing commercial business for Ada educators at several organizational levels.
- n. The population of reusable Ada components is on the rise.
- o. Significant investments are being made in the marketing of reusable Ada components.
- p. As a result of the large military investment in the WWMCCS upgrade effort, design tools, methodologies, reusable design and code are beginning to spill into the commercial world.



APPENDIX A

Survey Questionnaire

PERSON CONTACTED \_\_\_\_\_ PHONE \_\_\_\_\_  
COMPANY \_\_\_\_\_ DATE \_\_\_\_\_

PROJECT \_\_\_\_\_

DESCRIPTION OF PROJECT, SIZE OF PROJECT IN \$, MAN MONTHS, LINES OF CODE,  
BYTES OF OBJECT CODE, CURRENT STAGE OF PROJECT \_\_\_\_\_

RELATIONSHIP TO DoD PROGRAM OR COMMERCIAL MARKET (SOURCE OF FUNDING,  
REASON FOR FUNDING, DEFINITENESS OF FUNDING) \_\_\_\_\_

DESCRIPTION OF PRODUCT PRODUCED \_\_\_\_\_

PLANNED USES FOR PRODUCT \_\_\_\_\_

CONTACT'S ASSESSMENT OF OTHER COMMERCIAL USES OF PRODUCT \_\_\_\_\_

RELEVANT DATES; START OF PROJECT, COMPLETION \_\_\_\_\_

STATEMENTS ABOUT ADVANTAGES OR DRAWBACKS OF USING ADA \_\_\_\_\_

REFERRALS

--THE IDEA HERE IS TO GET A DIFFERENT PERSPECTIVE FROM THE SAME INDUSTRY  
OR SUBJECT AREA.

NAME \_\_\_\_\_ COMPANY \_\_\_\_\_ PHONE \_\_\_\_\_

NAME \_\_\_\_\_ COMPANY \_\_\_\_\_ PHONE \_\_\_\_\_

REFERRALS CONTINUED

NAME \_\_\_\_\_ COMPANY \_\_\_\_\_ PHONE \_\_\_\_\_

NAME \_\_\_\_\_ COMPANY \_\_\_\_\_ PHONE \_\_\_\_\_

NAME \_\_\_\_\_ COMPANY \_\_\_\_\_ PHONE \_\_\_\_\_

\*\*\*\*\*

INDEPENDENT EVALUATION OF ABOVE

SOURCE NAME \_\_\_\_\_ COMPANY \_\_\_\_\_

COMMENTS (ACCURACY, TECHNICAL CORRECTNESS, REALISM)

\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_

ANALYST \_\_\_\_\_ TIME SPENT \_\_\_\_\_

\_\_\_\_\_  
\_\_\_\_\_

APPENDIX B  
COMMERCIAL Ada APPLICATIONS IN COMMUNICATIONS

A number of studies have been conducted regarding errors that crop up in the complex software used in data-communications. Review of the software bugs most difficult to find and repair shows that a large number of these errors would have been caught by a language with strong typing features.

From a private telephone communication concerning an internal Bell Labs study of Modification Requests (M-R's) for a major switching system written in the "C" programming language the following information was elicited:

"This type of switching system entails hundreds of man years of development effort. The code is quite condensed, and closely resembles what DoD refers to as an "Embedded System".

The system had passed a full set of stringent internal test procedures. The M-R's were written after the system was operational in the field.

- o The M-R's were grouped as follows:

- o 50% were requests for changes to the existing design; additional capabilities, etc.
- o 25% were errors in design.
- o 25% were programming errors, of which: 1/2 were errors in logic, which according to the speaker could not have been caught by any compiler
- o 1/2 were errors in typing.

That is to say that 12% of M-R's and nearly 25% of all errors could have been caught by a language with strong typing across separately compiled units.

Another expert in a telecommunications company recorded his findings from a study of error reports in a major system:

"48% of the errors, those that were the most difficult to find and the most difficult to fix, were those dealing with the interface and could have been caught by an Ada Compiler".

"An error analysis of a large scale programming effort by TRW for RADC notes that the number of design errors discovered during or after acceptance test outnumbered the coding errors.

Furthermore, the average time to diagnose and correct design type errors was about twice that for coding errors"(11).

Finally, Haberman and Perry cite the advantages of packages and tasking in catching both typing and exclusion/synchronization errors (12).

Practical results are accumulating. Through the use of Ada as a design language in the DSM project, IBM not only experienced a significant reduction in errors per thousand lines of code (1.96) but found that the errors were so localized that only 1.8 modules (average of 280 lines of code each) needed updating to fix the errors. This project involved network control as well as real time satellite telemetry, commanding, and orbit prediction (13).

Drawing from actual experience within the Ada User Community, as reported in a paper presented to the Second National Conference on Using Ada, Thomas M. Pepper made the following statements in reference to reliability of several projects using Ada for Commercial Process Control Systems:

"...the systems developed run with virtually no unexplainable system crashes..." "...very few logic errors have been found once system integration and acceptance testing has been completed..."

He also stated that test time was reduced significantly:

"...procedures very often ran the first time tested..."

"...system integration time was shorter than expected..."(2)

In a presentation to the November, 84 National SIGAda Conference, Tony Brintzenhoff, Manager of the Ada Technology Operating Center for the Syscon Corporation in San Diego, CA, held that communications systems trends are creating the need for:

- o Increased modularity,
- o increased concurrent processing, and
- o increased software emphasis.

## APPENDIX C

### COMMERCIAL Ada APPLICATIONS IN PROCESS CONTROL

Grady Booch, a renowned Ada pioneer and developer of object oriented design for the language, pointed out during the taping of WORLD OF ADA, PART I, that the process control community had both a need for and an interest in the Ada language. Large factory control systems are extremely complex, and most often done in Assembly language. When a new system is developed, it almost inevitably starts from scratch, even though identical functions may exist in other systems. Progressive companies in the process control business began tracking Ada as early as 1981.

Professor Volz, Director, Center for Robotics and Integrated Manufacturing at the University of Michigan wrote in 1983:

"...significant extensions (to Pascal) make it the first practical language to bring together important features that include data astraction, separate compilation, multitasking, exception handling, encapsulation, and program abstraction through generics and operator overloading. These extensions make Ada particularly appealing for programming large scale real-time embedded systems -- a situation characteristic of robot-based

manufacturing cells." He also noted that,

"The software aspect of robot cell control itself encompasses a number of issues. Among the more important are:

- o the management of large complex software systems,
- o the efficiency of code produced for real-time applications,
- o interprocess communication and task synchronization,
- o portability,
- o program debugging, particularly the real-time aspects" (14).

The quotes above dealt with the use of Ada for Robot-Based Manufacturing Cells. These comments also apply to large process control applications.

There are two Postal contracts where Ada was proposed as the programming language. The first contractor was granted a waiver because at the time (in mid 1983) preemptive scheduling was not supported in the run time kernel for Ada, and task switch times were determined to be too long to meet the



performance requirements. The second contractor claimed that the embedded system support tools were not well enough along to meet their required performance within their scheduled time and budget.

Both contractors eventually saw the use of the "C" programming language as a more cost-effective alternative. Ada use would have involved a very substantial effort because of the lack of available tools, and because of the limitations of time and budget.

## APPENDIX D

### COMMERCIAL Ada APPLICATIONS IN THE TRAINING AREA

An article from TRAINING Magazine details the cost of training employees:

"The training budgets for U.S organizations with 50 or more employees totaled more than \$4 billion in 1984. This sum is up 37.2% from their estimate of 1983 budgets. This estimate does not include all funds spent by corporations on staff salaries, travel and expense. With these figures included the estimate grows to between \$5.05 and \$7.01 billion. Even these figures do not account for salaries and benefits paid to trainees during the time they spend in training. If you include these, the estimate rises to between \$7.07 and \$9.8 billion in 1984. Based on a wide reader survey, the 1985 budgets are up from these figures (15)".

Another estimate, by L.A. Parker, Director of the Center for Interactive Programs for the University of Wisconsin-Madison states that U.S. companies spend almost \$9 billion a year just for airfare, hotels, and meals for employees traveling to and from seminars" (16).

Because of the staggering costs of present training methods there is a strong motivation for corporations to look to other alternatives. In addition to this, some studies show a reduction in learning time using Computer Based Training of from 10% to 40% when compared to textbooks and even live instructional methods (17).

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